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REPORT NO. 88-30

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NAVAL MEDICAL RESEARCH AND DEVELOPMENT COMMAND
BETHESDA, MARYLAND

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ON EVENT-RELATED POTENTIALS

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*Report No. 88-30 was supported by the Naval Medical Research and Development Command, Department of the Navy, under work unit MR.001-6037. The views expressed in this article are those of the authors and do not reflect the official policy or position of the Department of the Navy, Department of Defense, nor the U. S. Government.

SUMMARY

Research has demonstrated high correlations between ERP components and selective attention. Applications include the evaluation of human performance, personnel selection, and workload assessment. A fairly consistent relationship has emerged between early negative components and selective attention, whereas positive components, such as the P300, have been shown to be related to recognition memory or decision making processes. Studies have also indicated that, as task difficulty increases, P300 amplitude decreases and latency increases. However, these studies were performed using naive college students as subjects. An earlier study by Kobus, Beeler and Stashover (1987) indicated that attentional resource allocation or electrical distribution differences may exist between subjects who are naive and subjects who have prior task experience. It was hypothesized that increased task difficulty might accentuate these electrophysiological differences. The present study investigated this hypothesis by increasing the difficulty in a simulated auditory sonar task.

Twenty male subjects were divided into two groups based on their sonar experience. Group one consisted of recruits who had been selected for sonar training. Group two was made up of experienced sonar operators with at least 4 years operational experience. Increased task difficulty was expected to produce increased differences between experienced and inexperienced subjects, particularly for the P300 component. A significant 3-way interaction for the P300 showed that amplitudes for both groups were greater for the attended condition at both the Fz and the Pz electrode sites. Attended trial amplitude values for the experienced group at the Fz electrode site were greater than for the inexperienced group, while amplitude values at the Pz site were greater for the inexperienced group.

INTRODUCTION

Over the last decade the use of electrophysiology as a tool to evaluate cognitive performance has developed into the emerging field of "cognitive psychophysiology" (Donchin, 1982). This field has attempted to correlate the surface electrical activity (EEG) of the brain with sensory and cognitive performance. EEG data are time locked to a stimulus presentation and averaged over a number of experimental trials. The resulting waveform is a composite of many different individual components, some of which may overlap in time. These components, referred to as event-related potentials (ERP's), are assumed to represent "far-field reflections of patterned neural activities associated with informational transactions in the brain." (Hillyard & Kutas, 1983, p. 34) Past research has shown high correlations between these electrophysiological components and selective attention, stimulus encoding, target recognition, and their relationship with various stages of information processing (Sutton & Ruchkin, 1984; Donchin, Karis, Bashore, Coles, & Gratton, 1986). The technique has proven useful for investigations in areas such as evaluating human performance (Wickens, Kramer, Vanesse, & Donchin, 1983), personnel selection (Lewis, 1983; Hord, 1987; and Stanny, Reeves, Blackburn & Banta, 1987), and workload assessment (Kramer, Sirevaag & Braune, 1986). Many of these studies have shown a fairly consistent relationship between early (< 140ms) negative components and selective attention; whereas later (> 250ms) positive components, such as the P300, have been shown to be related to recognition memory or decision making processes (Warren and Wideman, 1983; Cael, Nash & Singer, 1974).

Research has indicated that amplitude and latency values of the P300 may be affected by task difficulty. Isreal, Wickens and Donchin, (1980) have shown that as task difficulty increases, P300 amplitude decreases and latency increases. This effect has been shown to be most robust at the Pz electrode site. However, these studies were performed using naive subjects, and little consideration had been given to attentional resource allocation or electrical distribution differences which may have existed between naive and experienced subjects. Kobus, Beeler and Stashower (1987) found that individuals with several years of experience on operational tasks that were similar to the

experimental task displayed differences from naive subjects in the distribution of electrical activity of the brain. Results indicated that during an auditory "oddball task" naive subjects demonstrated larger amplitude differences, for the N1-P2 component, between attentional conditions at the Pz electrode site, a finding which is consistent with previous studies (Donchin, 1984). However, when the subjects were highly experienced, N1-P2 amplitude differences were greater at the Fz electrode site. It was suggested that differences in the distribution of electrical activity between the two groups may represent a different "mode" of processing (e.g., controlled versus automatic).

If experience is related to differences in the distribution of electrical activity of the brain during specific tasks, one might assume that if task difficulty were to increase, the amplitude differences found between naive and experienced operators would also increase. It was also hypothesized that as task difficulty increased, additional components (i.e., P300) might also display similar patterns of activity that would vary with levels of experience. The present study investigated these assumptions through the extension of earlier research by Kobus et al. (1987) and tested these hypotheses by increasing the difficulty in an auditory sonar simulated task.

METHOD

Subjects

Two groups of volunteer subjects were recruited from the Fleet Anti-Submarine Warfare School in San Diego. Ten inexperienced male recruits, with no formal experience or training in sonar, were assigned to Group One. All had been selected for sonar school based on scores they received on the Armed Services Vocational Aptitude Battery (ASVAB). Ages of the inexperienced group ranged from 18 to 29, with a mean of 21.3 years. Group Two included ten male sonar technicians with at least four years operational experience. The mean age for this group was 29.4 years, with a range of 25 to 38 years.

Apparatus

Event-related potentials were monitored and recorded using a Nicolet Compact Four Electrodiagnostic System (Model C4). EEG activity was sampled

for 800ms and averaged over trials. Internal system amplification was set at 100 microvolts. Internal low and high frequency filters were set at 1Hz and 30Hz, respectively. The program was configured with an artifact rejection routine which automatically eliminated trials accompanied by extraneous muscle or eye activity. All software for data collection, rejection and analyses are programs developed by Nicolet for the C-4 system.

Grass gold-cup electrodes were attached to the scalp with collodion at two midline electrode sites (Fz and Pz) and were referenced to linked mastoids in accordance with the International 10-20 system (Jasper, 1958). An electrode clip attached to the left ear served as ground. Electrode impedances were below 10kohms.

Stimuli were two 70db tones presented in a standard oddball paradigm (80/20; nontarget/target ratio). The tones were both presented at 500Hz and differed only in duration. This was the major difference between the first and the present study. Targets were 200ms in duration (50ms ramp and 150ms plateau). Non-target tones presented for 100ms (50ms ramp and 50ms plateau). A white noise background (80db) was presented binaurally throughout the testing session. All stimuli were delivered through a Telephonics headset (TDH-39p).

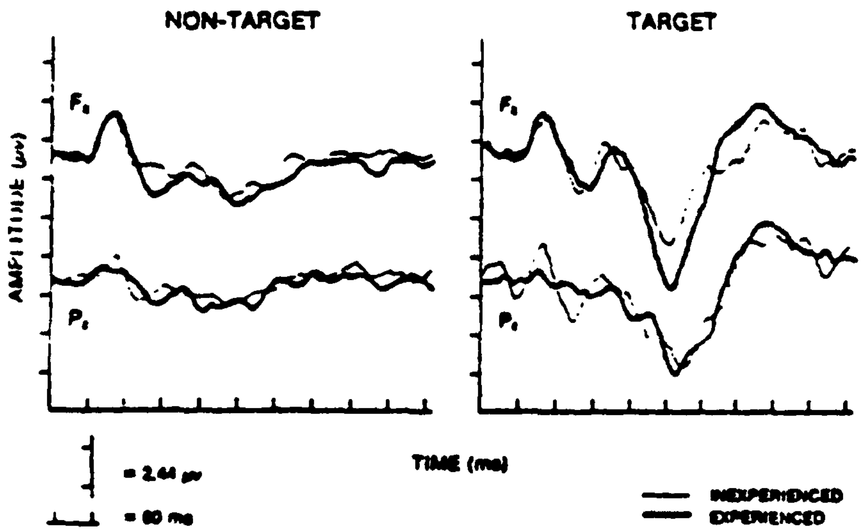
Procedure

The testing procedure was similar to the procedure used by Kobus et al. (1987) and lasted approximately 15 minutes. Subjects sat in a quiet, darkened room and listened to target and non-target tones presented binaurally. Subjects were asked to selectively attend to longer duration tones by counting them subvocally. Subjects completed two experimental runs, separated by a brief two to three minute break. Each run consisted of 100 trials, for a total of 200 artifact free trials collected within a single session.

RESULTS

Data were analyzed to examine differences between groups, experimental conditions and electrode sites. Group grand mean waveforms for each electrode site and each condition are shown in Figure 1.

Figure 1. The grand average waveforms for Experienced and Inexperienced groups, for both conditions, Target and Non-Target, at both electrode sites.



Peak amplitude values were located within specific latency windows and for specific components of interest (see Table 1). These included the N100, P200 and the P300. Latency values of each peak were also recorded. The difference in amplitude between the N100 and the P200 component (N1P2) was also determined.

TABLE 1. Latency Values for Moving Window Algorithms

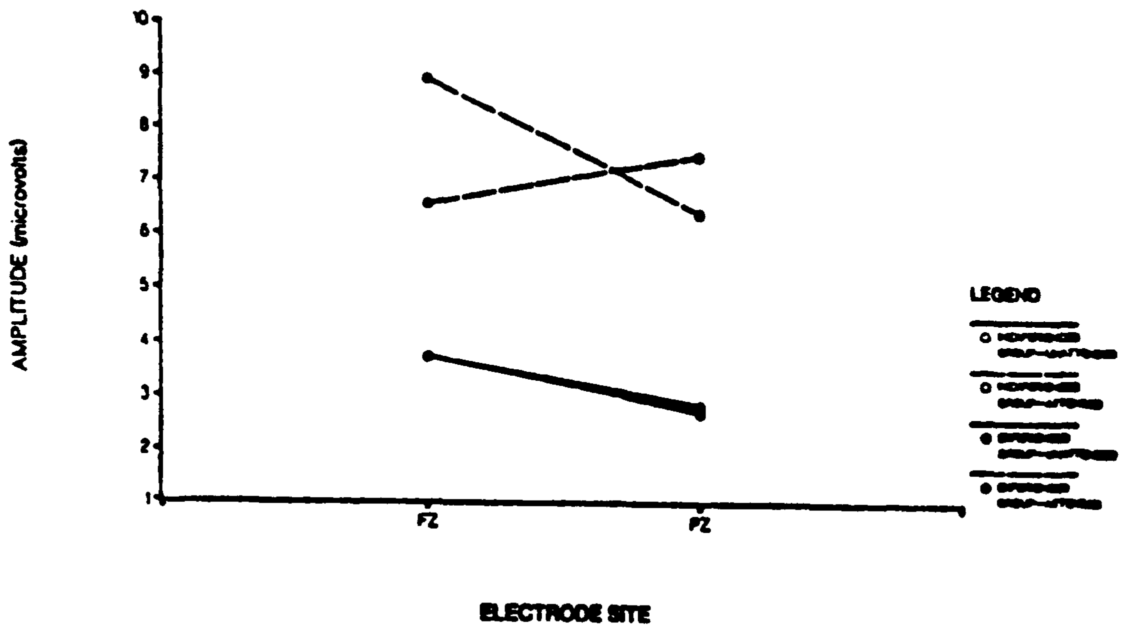
Component	Milliseconds
N100	50-150
P200	150-250
P300	250-500

A three-way (group X condition X electrode) analysis of variance was performed on total group data. Thus, all two hundred trials for each subject were included in the analysis of each component's amplitude and latency. Analysis of N100 amplitude data showed greater values at the Pz electrode site, $F(1,18)=5.79$, $p<.05$, regardless of condition or group. The same effect emerged in analysis of the N1P2 amplitude, $F(1,18)=51.84$, $p<.01$. No statistically significant differences were found for N100 latency values. Analysis of the P200 also revealed significant electrode site differences for amplitude, $F(1,18)=7.86$, $p<.01$, with Fz amplitude being greater. Latency for the P200 was significantly longer for the experienced group, $F(1,19)=11.23$, $p<.01$, regardless of condition or electrode site.

Analysis of the P300 yielded several statistically significant results. Electrode site amplitude differences were significantly greater at the Pz site, $F(1,18)=102.2$, $p<.001$. The main effect of experimental condition (nontarget versus target) also displayed significantly greater amplitude values, $F(1,18)=6.74$, $p<.05$, and longer latency values, $F(1,18)=9.02$, $p<.01$, on target trials for both groups. A significant group by electrode site interaction, $F(1,18)=5.88$, $p<.05$, indicated that amplitude difference values for the experienced group at the Fz electrode site were greater than amplitude difference values at the same site for the inexperienced group. The opposite was true at the Pz electrode site, where greater amplitude values were produced by the inexperienced group. A highly significant two-way interaction (electrode site X condition) for P300 latency was also found, $F(1,18)=16.49$, $p<.01$. Latency values at the Pz electrode site were longer for the target condition. No significant latency differences were seen between conditions at the Fz site.

A significant three-way (group X condition X electrode site) interaction was also observed for the P300 component, $F(1,18)=8.26$, $p<.01$. Amplitudes for both groups were greater for the target condition at both electrode sites. As shown in Figure 2 the amplitude value for the experienced group at the Fz electrode site for target trials was greater than for the inexperienced group, while the amplitude value at the Pz electrode site was greater for the inexperienced group.

Figure 2. Three-way interaction (Group X condition X electrode site for P300 amplitude.



Split-half reliability correlations were computed between runs to determine the reliability of component amplitude and latency for both electrode sites and both groups in the target condition. No significant correlations emerged for amplitude or latency values at the N100, the P200 or the N1P2 for either group at either electrode site. A significant correlation was found for P300 amplitude scores of the experienced group at both the Fz, $r=.74$, $p<.05$, and Pz, $r=.89$, $p<.01$, electrode sites and for latency values at the Pz, $r=.66$, $p<.05$, site. No significant correlations were found for the inexperienced group at the Pz site.

DISCUSSION

This study increased the difficulty of a sonar simulated task described by Kobus et al. (1987) to further investigate differences between highly experienced sonar operators and naive subjects who had been selected by the Navy for sonar training. Initial observations suggested that groups which differ in their level of experience demonstrate different patterns of electrical activity of the brain which may be indicative of differences between controlled and automatic processing (Kobus et al., 1987). Overall, the current results support these earlier findings.

As in the earlier study, trials requiring selective attention were compared with those that did not. Again, highly experienced subjects showed greater differences between these two conditions at the frontal site. In the original study, these differences were observed for the N1P2 component whereas, in the current study, these findings emerged at the P300. As noted earlier, past research has indicated that as task difficulty increases, the latency of electrophysiological components (specifically the P300) increases and amplitude decreases (Isreal et al., 1980). A comparison of the findings of the two studies supports this relationship. When task difficulty increased, the latency of P300 also increased regardless of group. The latency of the P300 in the first study was approximately 330ms for both the target and the nontarget conditions. In the current study the latency increased at least 40ms for both groups and both conditions. This finding may also explain the lack of a significant N1P2 difference in the present study. This may be a result of an increase in the latency of the P200 component. During the present study, the P200 component may have extended outside the time window specified by the analysis algorithm. If this were the case, the N1P2 effect would be lost with the increasing latency of P200. In addition, there is some support that as task difficulty increases P200 component amplitude decreases (Lindholm and Koriath, 1985). Although the test-retest reliabilities were low for most components, P300 was highly reliable. The low reliability found was probably due to the trial-to-trial variability that was amplified due to averaging over several trials. Therefore, single trial recording (and peak finding) is recommended for future studies.

The principal finding is that significant differences in the distribution of electrical activity emerged between the two groups. The naive group demonstrated greater amplitude differences between the conditions at the Pz electrode site, whereas, the experienced group displayed greater differences at the Fz electrode site. In addition, it should be noted that the reliability of the ERP waveform appears to increase with task experience (Lewis, Trejo, Nunez, Weinberg, & Naitoh, 1988). These results are consistent with the earlier study's findings and provides additional evidence that indicates that differences in the distribution of brain electrical activity may depend upon prior task experience. However, these results may also be attributed to the age related differences between the two groups. Strayer, Wickens and Braune (1987), have shown that greater amplitude differences are demonstrated frontally in older subjects. These results, however, were computed over an age range of five decades (20-70 years). Although the age differences in the present study were significant, they differed by less than a decade. The data displayed by Strayer et al. do not appear to demonstrate significant age-related changes over the first two decades. Although the results are preliminary in nature, these findings could greatly increase the utility of the ERP technique. Further investigations could explore monitoring the electrical activity of the brain as a dependent measure in the evaluation of training procedures and as an additional criterion variable for job placement. Further research is needed to address these future applications.

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ABSTRACT

Research has shown that increased task difficulty elicits decreased amplitude and an increase in latency for the P300 at the Pz electrode site. However, these findings have been based on research using subjects who are naive to the experimental task. Kobus, Beeler and Stashover (1987) showed that greater amplitude differences were found between target and non-target conditions at the Fz electrode site. It was suggested that differences in the distribution of electrical activity may be indicative of a shift from controlled to automatic processing. The current study built on this earlier work. Increased task difficulty was expected to produce an increase in the differences observed between experienced and inexperienced subjects, particularly for the P300 component. A significant 3-way interaction for the P300 showed that amplitudes for both groups were greater for the attended condition at both the Pz and Pz electrode sites. Attended trial amplitude values for the experienced group at the Fz electrode site were greater than for the inexperienced group, while amplitude values at the Pz site were greater for the inexperienced group. These findings provide additional support for the hypothesis that a redistribution of electrical activity of the brain may be indicative of a shift from controlled to automatic processing.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS N/A
2a. SECURITY CLASSIFICATION AUTHORITY N/A	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited.
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE N/A	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) NHRC Report No. 88-30	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION Naval Health Research Center 6b. OFFICE SYMBOL (If applicable) 30	7a. NAME OF MONITORING ORGANIZATION Chief, Bureau of Medicine and Surgery
6c. ADDRESS (City, State, and ZIP Code) P.O. Box 85122 San Diego, CA 92138-9174	7b. ADDRESS (City, State, and ZIP Code) Department of the Navy Washington, DC 20372
8a. NAME OF FUNDING/SPONSORING ORGANIZATION Naval Medical Research & Development Command 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code) NMC NCR Bethesda, MD 20814-5044	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. 61152N; PROJECT NO. MR0000; TASK NO .01; WORK UNIT ACCESSION NO. DN246584

11. TITLE (Include Security Classification)

Effects of experience and task difficulty on event-related potentials

12. PERSONAL AUTHOR(S)

Kobus, David A. & Stashower, Keren

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final	FROM ______ TO ______	13 October 1989	12

16. SUPPLEMENTARY NOTATION

17. COSATI CODES		
FIELD	GROUP	SUB-GROUP

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)

Electrophysiology, Human Performance, Task Difficulty.

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

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20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL Lt David A. Kobus	22b. TELEPHONE (Include Area Code) (619) 553-8417 22c. OFFICE SYMBOL Code 30

DD FORM 1473, 84 MAR 83 APR edition may be used until exhausted. All other editions are obsolete

Unclassified

UNCLASSIFIED

19. ABSTRACT (Cont.)

for the inexperienced group. These findings provide additional support for the hypothesis that a re-distribution of electrical activity of the brain may be indicative of a shift from controlled to automatic processing. Keywords: